

OBSERVATIONS ON THE NATURAL HISTORY
OF THE COMMON MUSK TURTLE,
STERNOTHERUS ODORATUS
(LATREILLE) *



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INTRODUCTION

"To tell American students that little is known of the habits of Turtles, the laying of their eggs, the growth of their young, etc., would perhaps excite a smile in those, who, as boys, have been in the habit of collecting Turtle's eggs, egg-hunting being an occupation of which boys are fond the world over. Yet so it is: what every inhabitant of the country may have seen again and again has not yet been collected in scientific works." — Louis Agassiz, 1857.

IT DOUBTLESS would be difficult for Agassiz, were he here at the present moment, to believe that his statement of 1857 has remained true for nearly seventy-five years. Nevertheless, as Babcock (1919) has written, "The same conditions, although to a far less extent, still exist. . . ." Much information concerning the natural history of most of the turtles of the world is still to be compiled and recorded, in spite of the extensive monographs by Agassiz and Babcock on these interesting animals. It is not my intention to attempt a collection of the facts presented in the literature on the natural history and habits of turtles in general. I wish, rather, to add some significant observations to the data available concerning the habits and life-history of one species, namely, the common musk turtle, *Sternotherus odoratus* (Latreille), known in some localities as the "stink-pot terrapin" and in others as the "little snapper." This paper gives the results obtained from incidental observations made in connection with studies on the development of this species, and they

seem worthy of record — especially so, since the small amount of information found in the literature is widely scattered, is sometimes erroneous, and, in many instances, requires confirmation.

GENERAL CONSIDERATIONS

The musk turtle, *Sternotherus odoratus* (Latreille), occurs in great numbers in the region about Ann Arbor, Michigan, especially in the many and easily accessible fresh-water lakes. The majority of these observations were made at Whitmore Lake, an inland lake about twelve miles north of Ann Arbor. Additional materials were obtained from other lakes, including Pleasant, Portage, and Base-line, as well as from the Huron River.

The species is widely distributed and is generally abundant. Its range extends from southern Canada south to the Gulf of Mexico and west to Illinois and Wisconsin in the northern part and to Texas in the southern (Ditmars, 1907).

General descriptions of *Sternotherus* have been given in numerous places in the literature and need not be repeated here. The reader is referred to Ruthven, Thompson, and Gaige (1928) for a complete taxonomic description of the species here described. The carapace is oval in outline and is considerably arched. The plastron does not nearly fill the opening of the carapace, and is narrow, short, rounded anteriorly, and emarginate posteriorly. The anterior part of the plastron is slightly movable on a transverse hinge between the abdominal and the pectoral scutes. Areas of skin separate all the plastral scutes of the adult. The neck is long and the head large, with a conical, tapering snout. The skin is soft and covered with numerous fleshy papillae. There are two or more pairs of barbels or enlarged papillae on the chin and the throat. The coloration is of a dull brownish or olive tint, sometimes marbled or mottled with lighter olive or brownish yellow. Gadow (1920) states that "The only ornamental colouring is a pair of clear yellow broad lines on each side of the head, and a similar streak on each side of the lower jaw." The carapaces in the oldest and largest specimens I have seen have never exceeded 122 mm. in length.

The musk turtle received its common as well as its specific

name, *S. odoratus*, from the strong musky odor which it gives off when captured or handled. Babcock (1919) says: "A pair of inguinal glands secretes a disagreeable and penetrating odor of musk from which it derives its name." However, the odoriferous glands are not all in an inguinal position. I have been unable to find any in such a situation, and if they are there at all, they play a minor rôle in the secretion of the odor. Careful examination of a newly captured specimen from which the musky odor emanates reveals an orange or yellowish orange fluid along the border of the carapace at four separate and distinct places, two on each side. One gland is at each of the postero-lateral edges of the bridge, where it meets the carapace; another is on each side at the junction of the skin and the carapace, about midway between the anterior edge of the bridge and the cephalic end of the carapace. At each of these places a small white or yellowish pad of skin projects over the edge of the carapace, where it is usually possible to see the aperture of the duct which leads from the gland. These observations were made independently before I was aware that Dahlgren and Kepner (1908), who studied the musk glands of this turtle histologically, had already described their location. In an embryological study Stromsten (1917) describes their similar position in *Caretta caretta*. Morgan (1930) also confirms the description. Their statements make no reference to an inguinal position of musk-secreting glands in turtles. It is highly probable that there are no inguinal odoriferous glands in them, as there apparently are in some other reptiles, e.g. the alligator.

The musk turtle is strictly an aquatic form, being seldom found on land except during the egg-laying season. The thick, decaying vegetation in the shallow water along the shores of bayous affords an excellent hiding place and feeding ground. This turtle is often observed in the vicinity of muskrat houses, which are built mainly of the sedges that are abundant in these areas. Hay (1892) observes that "It appears to be disposed to frequent the deeper parts of ponds and small lakes, since in such places it is safer than about shores or on land." Newman (1906) believes that it goes into deeper water after the breeding season, since he could find no specimens during the summer months. However, I have been

able to find a certain number of specimens at all periods of the year, except in winter when the lakes are ice-covered. The number in shallow water is somewhat smaller during the summer season, but this is apparently a natural result due to increased activity during the warmer weather and to a wider range of distribution. There is probably no general change in habitat from the shallows during the breeding season to the deeper waters for the summer, that is, in the way of a uniform migration.

Hay further states that "They are often seen basking in the sun on some projecting rock or on some fallen tree, from which on the slightest alarm they drop off into the water." Newman, on the contrary, failed to observe musk turtles sunning themselves, as so many species of turtles are in the habit of doing. I have seen but two individuals under such conditions, and both of these were on fallen trees in the Huron River. When members of this species rest or sun themselves, they usually do so without leaving the water, for they are often found floating motionless on the surface, with only the top of the carapace visible. Newman has also observed this habit. He has encountered specimens of *S. odoratus* on land "at dusk, crawling about in the grass." The females are often seen on land during the egg-laying season, and especially toward evening. Occasionally individuals of both sexes have been captured while they were crossing highways which border lakes; such land excursions, however, are apparently infrequent. Babcock (1919) also indicates that "This animal is strictly aquatic in its habits, seldom, if ever, leaving the water, except to deposit its eggs; hence, it is not commonly known." Their habit of remaining in the water and in hiding has concealed them from many of their enemies, as well as from the observations of man. The species is, however, one of the most abundant.

HIBERNATION

In the winter, when the musk turtle is inactive, it probably buries itself in the mud beneath heavy vegetation. Babcock (1919) says that "Upon the approach of cold weather, it burrows into the mud and hibernates until spring." The close association of this turtle with the habitat of the muskrat suggests that musk-

rat holes and burrows might offer excellent hibernating conditions. Wetmore and Harper (1917) report the discovery of a specimen of *Kinosternon pennsylvanicum* (Bose) immediately after its emergence from hibernation on land. It was covered with freshly dried earth, and a search resulted in the discovery of a burrow beneath a dense growth of smilax. This burrow was about 9.5 inches deep, large enough to allow the turtle to enter without difficulty. They write: "Several fresh shells of *Aroemchelys* (*Sternotherus*) *odoratus* and one or two of *Kinosternon pennsylvanicum* were seen lying about in wooded areas bordering this same marsh. Thus the emergence of these turtles had been of interest to others." This statement apparently implies that *S. odoratus* may also hibernate on land. Information on the subject of hibernation of turtles appears to be inadequate and somewhat fragmentary. It is difficult to make observations upon hibernating turtles in nature, and also in the laboratory. Numerous statements in the literature only indicate the probability that the turtles bury themselves in the mud during the winter months, or in burrows on land, and, in the case of *Cistudo*, under decaying materials (Gadow, 1920; Rollinat, 1899).

In the early spring the animals may be captured with a net by scooping up a few inches of mud and débris from lake bottoms. They are usually in shallow regions where the water is from one to two feet in depth. When discovered in this manner they are very inactive, and the heads and legs are drawn well up into the shells. The carapaces at this time are usually covered with thick growths of algae. In most of them these coverings disappear as the season progresses and as they become more active. The green color of the algae is of material advantage to them, since it serves as a camouflage when they are in the water. The disappearance of the algae may be due to a shedding of the horny scutes to which they are attached, or it may be the result of constant friction of the carapace against the weeds and sticks among which the turtles are moving. That the scutes are shed at odd times is a certainty, but whether or not this occurs regularly each spring is unknown. Animals kept in the laboratory always exhibit this moulting or sloughing of the horny scutes of the plastron

and carapace. In nature, the scutes may be found along the lake shores and also in the water.

The earliest dates of collection were March 25, 1928, and March 23, 1929. Both sexes probably emerge from hibernation at about the same time, although the early collections show a larger number of males. This might indicate that the males appear somewhat earlier than the females. Young animals make their appearance about a month later, near the first of May.

SEX RATIO

In the spring of 1930 a series of collections of adult specimens was made in an effort to obtain data on the sex ratio in this form. An examination of 255 individuals showed a large predominance of females, which outnumbered the males in a ratio of 1.0 to 2.3. The materials from which the figures are taken are presented in Table I. If the collections which were made after the breeding season (May 20, 1930) are omitted, the 161 animals taken earlier in the spring show an excess of females in a ratio of 1.0 to 1.65. The number is small, but the figures may have some value, since so little is known concerning the sex ratio of animals in nature and of those used infrequently in genetic studies.

At the United States Fisheries Biological Station at Beaufort, North Carolina, Hildebrand (1929) has found that in the diamond-back terrapin (*Malaclemmys centrata* and *M. pileata*) the males are fewer than the females in a ratio of 1.0 to 4.4. This is a striking deviation from the expected sex ratio of 1 to 1, but the numerical difference exists in both selected and unselected lots at the terrapin breeding farm. Since the sex of young individuals cannot be determined by external characters until a length of about three inches has been attained, no data on the sex ratio were obtained from newly hatched animals. If a 1 to 1 sex ratio occurs in the young terrapins, it seems probable that numerous males fail to reach maturity because of a high mortality rate. Hildebrand concludes that "Such a supposition does not appear to be tenable, however, because the number of deaths in some of the lots was too few, even if males only had died, to make a ratio of 1 to 1."

These are the only statements in the literature concerning the sex ratio of turtles, and it is interesting to note that they both indicate a dominance of the female sex.

TABLE I

DATA ON SEX RATIO OF *S. ODORATUS* (LATREILLE)

Date of collection	No. of specimens	Males	Females
MICHIGAN, 1930			
Whitmore Lake			
April 25.....	2	1	1
" 29.....	7	2	5
" 30.....	8	4	4
May 4.....	79	31	48
" 11.....	2	1	1
" 14.....	49	19	30
" 25.....	5	2	3
" 30.....	30	5	25
June 14.....	59	9	50
Silver Lake			
May 3.....	14	3	11
TOTALS.....	255	77	178

BREEDING HABITS

Throughout the spring both sexes are found in the same areas, and they are closely associated until the middle or latter part of May, after which the males apparently begin to disperse (Table I). The females remain in the shallow areas near the shores until their eggs are deposited, when they, too, leave the breeding grounds. As many as thirty specimens have been taken within a radius of fifteen feet. Hallowell (1856) reports that 259 individuals have been taken from a single hole; this was in Pennsylvania. The close association of the sexes during the month of April and the early part of May is taken as an indication that mating occurs during that period. Unfortunately, I have been unable to make any actual observations of mating pairs. Numerous individuals have been kept in the laboratory during this

period and have been carefully watched with the hope that the courting and mating activities might be observed. Several times I have come upon a pair which were apparently mating, but these were below the surface of the water. Upon being disturbed, however, they immediately broke away from each other, so that no observations of copulation could be made. During copulation the plastron of the male is superimposed upon the carapace of the female, but no further details of the mating can be given. In the field, as well as in the laboratory, numerous individuals have been observed in their courting activities. The males are the aggressors, continually following the females about. So far as I can determine, there are no data on record on the copulation of this species. Cunningham (1922) has presented some information concerning this act in *Chrysemys cinerea*, and Morgan (1930) in *Clemmys insculpta*, but these seem to be the only available references on mating of turtles.

The fact that the eggs are first found in the oviducts about the middle of May indicates that mating activities are concluded for the season at that time. Furthermore, testes taken from males during the latter part of May show the beginning of a new spermatogenetic cycle and of what seems to be a degeneration of spermatozoa. The latter condition, however, requires further investigation. The number of spermatozoa, normally stored in the epididymis and in the seminiferous tubules of the testis, is greatly reduced, and the testis and epididymis have reached a minimal size by the latter days of May. Motile spermatozoa are found in the oviducts of the females, even in summer following egg-laying. Barney (1921) segregated ten female diamond-back terrapins from males. They continued to produce fertile eggs for four successive years. This is apparently one of the longest periods during which spermatozoa have been known to live and remain functional in vertebrates. It is on record that the sperm introduced into the oviducts of bats, certain snakes, and some salamanders remain functional for as long as a year, but in chickens they will fertilize eggs for only the next twenty days following copulation (Marshall, 1922).

In the oviducts of all females of the musk turtle examined

during the period following emergence from hibernation there were great numbers of motile sperm. It seems improbable that copulation could occur during hibernation, since the animals are extremely inactive at that time. Accordingly, mating had already occurred either in the spring of the year after emergence or at some time the year before, possibly in the fall or late in the summer, and the sperm had remained alive and functional in the oviducts throughout the winter. If the latter alternative is true, as stated by Agassiz (1857) and Evermann and Clark (1920), it seems probable that mating occurs in both the spring and the fall. During the summer the number of mature sperm is reduced in the males, and the new spermatogenetic cycle is not completed until the latter part of August. The time of breeding is apparently closely associated with, and may be dependent upon, the condition of the male sex glands. Rollinat (1899) records the following interesting observations on the breeding habits of *Cistudo europaea* (Dum. et Bibr.): "Les mâles sont en rut pendant presque toute l'année. Sauf en décembre et janvier, j'ai vu des mâles fixés sur des femelles pendant tous les autres mois, même au commencement et à la fin de l'hivernage, car cette Tortue hiverne aussi bien dans la terre ou le fumier; j'ai souvent observé plusieurs mâles superposés sur la même femelle! J'ai eu à déplorer bien des fois la mort de femelles noyées par des mâles qui les fatiguaient en restant plusieurs jours fixés sur elles; des mâles furent noyés par des individus du même sexe!" Mating is probably resumed in the spring at the point at which the onset of winter interrupted it in the preceding fall. It seems certain that mating does occur each spring at some time before ovulation and the entrance of the ova into the oviducts, although it obviously is not necessary for the annual production of fertile eggs, as shown by Barney's experiments.

Ovulation usually occurs between the 15th and the 20th of May. I have never observed a second period of ovulation, or of egg-laying, in a single year. Some species of turtles may produce two sets of eggs a year (Gadow, 1920), but *S. odoratus* is not one of these. Although many specimens have been examined before and between these dates, I have never seen a single egg in the

oviduct which did not have the shell membrane and some albumen already laid down; nor have I ever seen an ovum in the abdominal cavity immediately after ovulation. The eggs remain in the oviducts for a period of from twenty to thirty-five days, after which they are usually laid; this is the normal length of time required for the secretion of the albumen and the shell. At the same time it is interesting to note that embryonic development is retarded while the egg remains in the oviduct, so that at the time of laying the embryo is in an early stage of gastrulation. The rate of cleavage is extremely slow in comparison with that in other vertebrates. Twenty days or more are required for the embryo to complete the cleavage stages.

Under extreme conditions eggs may be retained in the oviducts for extended periods. Agassiz (1857) reports a case in which only one egg was deposited, in the middle of July. Some specimens which I kept in the laboratory did not deposit their eggs until the first of August, when only one or two were laid instead of the usual three or four. These were opened after a few days and the embryos were living, but in a very early stage of development. There is every indication that the developmental process would have continued had they not been opened and had the embryos not been killed. One specimen apparently did not deposit any of her eggs. She was released with others in the fall, and is believed to have been recaptured the following spring, although she had not been marked for identification. When this turtle was opened, three newly formed eggs were found in the oviducts, and three with intact shells and disintegrated contents were in the abdominal cavity. Only three empty follicles were in the ovaries, indicating that only three eggs had been produced that spring. If this condition was not caused by the retention of the specimen in the laboratory during the summer of the year before, and if it occurred under natural environmental conditions, it is of still more interest and significance. It implies a reversal of the normal direction of passage of eggs through the oviducts, a phenomenon heretofore unknown in turtles. The factors (reversal of ciliary motion in oviduct, anti-peristalsis, etc.) producing the reversal in direction are problematic.

Eggs were collected for the first time on June 10 in 1928; on June 7 in 1929; and on June 14 in 1930. Some had undoubtedly been laid a few days earlier, to judge from the degree of their development. In the summer of 1928 a female was discovered on the morning of July 17. She was on land, evidently seeking a spot to deposit her eggs. She was taken to the laboratory, where it was found upon dissection that the oviducts contained five eggs ready for deposition. This is the latest recorded date on which eggs ready for laying have been found in the oviducts of individuals of this species under normal conditions. Newman (1906) observed that eggs were deposited as late as June 25. The egg-laying season in this region may be considered to be during the last twenty days of June and the first five of July, during which period most of the eggs are deposited.

The number of eggs laid under normal conditions varies from two to seven, but is usually from three to five. Hay (1892) states that "They lay their eggs on shores in holes that they have dug in the sand with their hind feet. The eggs are from three to five in number, of an elongated elliptical shape, and have a hard smooth shell." Newman (1906) records that "Specimens were captured on land with eggs in the oviducts ready to be laid, on the following dates: June 11, 16, 20, 22, 23, and 25. In no case did I find more than three eggs in the oviducts. These were elliptical in form and nearly as large as the eggs of *Chrysemys*. The shell is hard and of a china-like consistency, brittle but capable of withstanding considerable pressure." Several specimens that I have examined have had more than three eggs in the oviducts. Two exceptionally large ones had seven and nine eggs. Clutches have been uncovered which contained two, three, four, five, and six eggs, but those with three to five are the most common.

Newman (1906) makes the following observations upon the nesting habits of *S. odoratus*: "On only one occasion did I have the good fortune to observe *Sternotherus* in the process of nesting. When I first encountered the little tortoise she was digging in some soft soil, using all four feet and her snout. On my approach she abandoned her work and wandered about for fully an hour trying different places. Finally, she selected for nesting a decayed

stump that had rotted down level with the ground. She dug with fore-feet and hind-feet a shallow hole about two inches wide and of about the same depth, and deposited two eggs therein. After covering these eggs with excavated débris, she went her way. The form and workmanship of this little nest were of an inferior order as compared with those of other species of tortoise I have observed." I have had the opportunity to observe several females in the act of nesting, which apparently may take place at any time of the day from early morning till twilight. None have been found nesting at night, although it is quite possible that they do so. Agassiz (1857) saw them laying at half-past eight in the evening. The nests I have seen in the sand were built in much the same manner as the one described by Newman and were of a similar type. They were on a sandy shore from about two to five yards away from the water, usually at the base of a tall weed or a clump of grass. Very often the eggs are not completely covered when the turtle leaves the spot of laying.

Eigenmann (1896) gives the following account of the egg-laying habits of *S. odoratus* at Turkey Lake, Indiana:

The eggs are laid in the rotten wood on the tops of stumps standing in the margin of the lake. The turtles were frequently found in the tops of these stumps, and some of their eggs were wedged into the rotten wood as far as the finger could bore. Rotten logs removed some distance from the water are also favorable places for egg-laying, and in a mucky place of small area at the edge of the lake, 362 eggs were taken at one time. . . . While passing along a wheat field some turtles were seen coming from it, and on inspection it was found that they had deposited their eggs in depressions made by a cow while walking over the ground when it was soft. Still other eggs were found in bundles of rushes drifted together.

An interesting change of habit seems to have taken place among these turtles during the past fifty years. Before that time the number of stumps standing in the margin of the lake must have been exceedingly small. The present large number is due to the rising of the lake after the building of the dam and the subsequent cutting down of the trees whose boles had become submerged. The habit of laying eggs in stumps cannot be of much more than fifty years' duration.

It would be interesting to determine whether this change of habit has occurred in other places under similar circumstances. I have also found numerous eggs in rushes that have drifted together along the shore.

The size of the eggs is variable, and apparently is dependent upon that of the female and the number of eggs laid (Fig. 78). For example, nine eggs removed from a very large female were all of minimum size, but three eggs removed from an average animal were of maximum size. Measurements were taken from a small

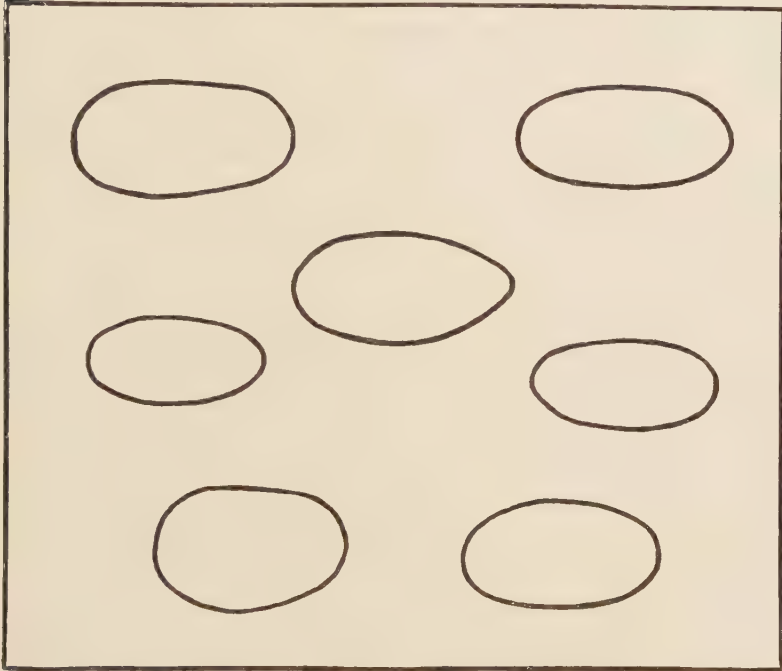


FIG. 78. Outline drawings of eggs of *S. odoratus* (Latreille), showing some variations in size and shape. $\times 1$

lot of seventy-five eggs. The maximum length from tip to tip was 31.0 mm.; the minimum length, 24.0 mm.; the average, 27.1 mm. The maximum diameter of the eggs varied from 14.2 to 17.0 mm., averaging 15.5 mm. The variation in the size of the eggs also gives some index of the variation in the size of the young at hatching. Babcock (1919) says: "The young when newly hatched, are one-half inch long (length of carapace, which

is soft and pliable)." This figure, according to my results, seems much too small. Measurements made of two hundred specimens, which had been newly hatched from eggs kept in the laboratory, show the carapaces to be at least 19.0 mm. in length, to average 23.0 mm., and sometimes to reach even 25.0 mm. Babcock's specimens were apparently about one third smaller than mine. This is quite a variation, but, since Babcock's work was done in New England, it may be due to seasonal differences in different regions of the country.

The incubation period of the eggs of this species is also somewhat variable; however, embryos kept in the laboratory usually hatched in from sixty to seventy-five days after the eggs had been laid. This figure may be somewhat low, since the data were taken from embryos that had been kept in a room which occasionally reached a high temperature (37 degrees C.). Fluctuations in temperature and humidity play an important part in the regulation of the rate of development. This has been determined by direct observation. I have obtained many embryos during the summer, and when one is preparing a graded series of embryonic stages, slight changes in the growth rate are easily detected. At times the growth seems to be at a complete standstill; it has been noted that such modifications correspond to some direct change in the temperature or the amount of moisture in the incubating medium. During three summers the incubation period of eggs kept in the laboratory has fallen within the stated period. By keeping eggs in the basement of the laboratory, where the temperature rarely exceeded 25 degrees C., the incubation period was lengthened to approximately ninety days. Added moisture during the latter days of incubation delayed hatching until an optimum humidity was attained, but it also resulted in the death of numerous embryos. A number of eggs were collected from the natural environment on September 5, 1931. Some had already hatched, as evidenced by the broken shells, but no turtles were seen. They must have taken to the water near by, where the young are very well hidden from detection. Numerous eggs have been found in the spring; examination revealed the remains of embryos in them, but none of them were living. It seems that

the onset of cold weather may often interfere with the incubation period, prolonging it so much that the young never hatch; some turtles apparently pass the winter months in the egg and hatch in the spring (Gadow, 1920).

Favorite nesting places for the musk turtle are the houses of muskrats. Two houses examined on June 19, 1929, contained 196 and 253 eggs. One turtle was disturbed in the act of digging into a house, and another was on its nest. On June 10, 1928, 127 eggs were found in a single house; on June 17, 1928, one week later, the same house yielded 52 more eggs. Hankinson (1907) has pictured the eggs of the same species as he discovered them in a muskrat house at Walnut Lake, Michigan. A great number of the eggs laid on the shores and in the fields are dug up and eaten by foraging mammals, probably skunks, chipmunks, raccoons, and possibly others, although I have never personally observed the offenders. The tracks left near the nest are small, and are obviously those of some rodent. Their ability to find the turtle nests is quite remarkable, for very few eggs can be discovered after a nesting ground has once been visited by them. Only empty broken shells remain strewn around the neatly gouged-out nests. It seems likely that some birds, such as crows and herons, are also responsible for the destruction of some eggs. Both crows and herons have been observed on the tops of muskrat houses, which are often literally torn to pieces, in which case there are practically no eggs. Almost every house that is intact contains numerous eggs, whereas those which have been torn up by the birds have only a very few. They have probably been laid since the birds last raided the house, or have been overlooked. It is rather doubtful whether any land mammal would make excursions into the water for the express purpose of obtaining the eggs laid in the muskrat houses, and this makes it more probable that birds are the offenders in such instances.

HABITS AND FOOD

An examination of the stomach contents of numerous specimens shows that the species is a scavenger, and that it is omnivorous in its food habits. Newman (1906) has seen turtles feeding on land

snails, and he also states that they will eat anything given to them. Remains of fish, clams, snails, aquatic insects, and crabs, as well as much vegetable matter, such as buds of *Elodea* and other unidentified aquatic plants, have been found in their stomachs. Babcock (1919) says: "The Musk Turtle is principally carnivorous, feeding on small fish, aquatic insects, worms, fish eggs, pollywogs, and other small forms of animal life. It often takes the worm-baited hook of fishermen. One of my very small specimens (carapace length, $1\frac{1}{16}$ inches) attacked and devoured, whole and alive, an earthworm twice its length in exactly sixty-five seconds." Surface (1908) found snails, crickets, grasshoppers, larvae of *Lepidoptera*, and beetles in the stomachs of four specimens. I have used dried ant larvae, *Elodea* buds and leaves, earthworms, chopped liver, and beefsteak to feed young laboratory animals. They seem, however, to prefer live earthworms to anything else.

Babcock (1919) also records the following statements concerning habits of this turtle: "Its disposition is pugnacious and vicious, somewhat resembling that of the Snapping Turtle. It differs from the latter, however, in its method of snapping, for instead of quickly throwing out the head with a force that brings the whole body into play, it slowly stretches out its neck toward the object before snapping. The males are said to produce 'stridulating sounds' by rubbing together the patches of horny tubercles which occur on the hind legs, but I have never observed it." Gadow (1920) says that "It is mainly aquatic, and is one of the dullest and shyest species." It is most certainly dull, for a small amount of harmless teasing or rough treatment will induce it to turn its head about and bite itself severely. Its method of snapping is indicative of its cautiousness and shyness in attacking any object. The resemblance of its attitude to that of the snapping turtle is striking, and it is commonly known among fishermen of the region about Ann Arbor as the "little snapper," because of its pugnacious tendencies. In reality, it is quite harmless and easy to handle. As regards the "stridulating sounds" produced by the males, although I have heard such sounds coming from a laboratory aquarium which contained several musk turtles,

I have never been able to ascertain with any degree of certainty how they were produced, nor have I been able to determine that they were made only by the males. Babcock apparently obtained his information from Boulenger (1914), who states that "The back of the legs of the males in some of the species bears two patches of horny tubercles, and by rubbing these against one another stridulating sounds are produced very similar to those so well known in grasshoppers." The sounds may be produced in the manner suggested, but, on the other hand, they may be the result of some respiratory mechanism, similar to that in the alligator (Reese, 1931), or in other turtles (Gadow, 1920; Boulenger, 1914). Movements of the muscles of the throat that have been observed by the writer at the time of the sounds may be the responsible factor.

GROWTH AND AGE

Little is known about the growth rate of most turtles, and much of the available data has been derived from studies of growth under laboratory conditions, or in the terrapin farms (Hildebrand, 1929). It has been a popular belief that turtles are as slow in their growth as they are reputed to be in their motion, habits, and general metabolic activities. After presenting graphs showing the growth of the loggerhead turtle (*Caretta caretta* Linn.) over a period of four years, Parker (1926, 1929) concludes "that turtles, even large ones, may reach maturity at a comparatively rapid rate, and that the opinion commonly entertained of their great slowness of growth is scarcely justifiable. Without doubt their increase in late life is very slow and this may have given occasion for the belief in a low rate of growth in general."

In 1857 Agassiz gave the following growth chart for *Chrysemys picta*:

Year	Carapace length	Year	Carapace length
2	26.5 mm.	9 (♂)	74.0 mm.
3	42.0 mm.	10 (♂)	77.0 mm.
4	51.0 mm.	11 (♂)	80.0 mm.
5	54.0 mm.	14 (♀)	92.0 mm.
6	59.0 mm.	25 (♀)	121.0 mm.
7	66.0 mm.	Old (♀)	129.0 mm.
8 (♂)	72.5 mm.	Very old (♀)	163.0 mm.

The size given for the second year is that of the first spring after hatching, and the same relations are retained throughout the table given above. During the early years the rate of growth is very uniform, so that by the size differences only it is possible to arrange into sets of the same age younger specimens collected at the same time. Concentric lines of growth on the scutes indicate the number of years of age, and are valuable in confirmation of the size differences.

Pearse (1923) has shown that the western painted turtle, *Chrysemys cinerea* Bonnaterre, nearly doubles its length and weight during the second year of its life, increasing 73 per cent; during the third year, it increases 31 per cent; and during both the fourth and fifth years, 25 per cent. From this point on growth is slow, with an average increase of 5 per cent a year. An attempt was made by Pearse to correlate the size of this turtle with its age, but as Hubbs (1924) has pointed out, he neglected to indicate how the ages of the animals used were determined. Pearse, Lepkovsky, and Hintze (1925) studied the growth and the chemical composition of three species of turtles fed on rations of pure foods over periods of four and eleven months. This report, however, gives little information concerning the normal growth rate in natural environments.

Many of the data on growth of turtles have been compiled at the station for the culture of the diamond-back terrapin at Beaufort, North Carolina. Barney (1922) found that they may attain a length of from 130 to 150 mm. in four years, provided they are fed in winter. The same range of length was reached in six or seven years when they were allowed to hibernate. The maximum increase in length recorded by Barney was 81 mm. for a single year, and 104 mm. for two years. Hildebrand (1929) has recently completed a study of the growth of the same species. All the specimens were under direct observation for a period of from five to fifteen years. Variations in the growth of winter-fed and hibernating terrapins are discussed fully. There is a relatively slow growth after an age of from eight to ten years is reached. Whether specimens which are kept in captivity continually present the same conditions as those of a normal environment remains to be determined.

Agassiz (1857) says: "We find upon the surface of each scale, around a small angular plate [the plate of the first year's growth], a smaller or greater number of concentric stripes or regular annular rings, as they are exhibited on a transverse section of an old tree." It is possible to determine the age of young turtles by the number of the rings on the scutes. Coker (1920) has tabulated a series of measurements of diamond-back terrapins, and has been able to determine their ages by counting the annual rings. In his discussion of this method of age determination, he says:

As the terrapin grows each scute extends its area peripherally and, commonly, in all directions. Thus with each period of growth, a ring of new tissue is added, separated from the central area (areola), or the preceding ring, by a line of depression. While these rings are spoken of as "concentric," the term must be taken with reservation, for growth is not equal in all directions. On the contrary, all scutes, except those of the anterior margin of the carapace and plastron, grow more anteriorly than posteriorly; hence, the rings are decidedly excentric, the center of each ring being (on most of the scutes) anterior to that of the preceding ring.

This same formation of growth rings occurs in *S. odoratus*. Certain difficulties, however, arise when attempts are made to calculate the age of a specimen in this manner. Coker has already pointed them out, as follows: (1) a more or less distinct line is produced by any cessation of growth, and by the resulting subdivision of each annual ring; (2) older shells become smooth through the repeated shedding of the horny layers; and (3) the growth of the older turtles is so slow that the rings are too small to be distinguished. Parker (1929) calls attention to the fact that early growth is subject to temporary cessation due to fluctuations in environmental conditions. After the musk turtle has passed its tenth year, it becomes almost impossible to determine its age by the ring criterion. Up to the age of ten years the method is reasonably accurate, but only in the cases of even younger specimens (two to seven years of age) can the age determination be made without some confusion. Benedetti (1925), in her study of the growth of *Testudo graeca*, was also able to determine only the age of younger specimens by counting the rings. Of 340 individuals used in her experiments, 94 could not be classified as to age on the basis of the number of annual rings. She concludes

that growth is not uniform, but that it varies with the seasons of the year, as, of course, would be expected. She finds also that growth varies with the size of the individual, as well as with the sex.

The oldest and largest members of *S. odoratus* seldom exceed 120 mm. in the length of the carapace. No sex differences are found in its length (Risley, 1930), as there are in numerous other species. As already stated, there is considerable variation in the size of the young at hatching (carapace length, 19.0 to 25.0 mm.). In 77 individuals, collected at large, it was possible to determine the number of rings on the scutes. These were found to form several definite age-groups, and measurements of the carapace length showed a corresponding arrangement into sets. The data have been plotted in the accompanying frequency curve (Fig. 79). The curve is based upon the average carapace length and the age of each group, and the variations are indicated. The variation within each group is not so great as would be expected if the variation at hatching were considered. Though the number of specimens available lessens the significance of the data considerably, I feel that the figures are not without importance. It is very difficult to discover the younger animals, and for that reason the number is small. Agassiz (1857) states that he hired a hundred men to hunt small turtles for him, but that, in a summer's work, they were unable to find a single one. In general, the data offer little that is new on the subject of growth of turtles, although they confirm the observations of Agassiz, Coker, Pearse, and others who have worked on other species. The figures do correlate the size of the turtle with its age, and therein find justification. I am confident that anyone can use these age-groups, and that, by calculating the carapace length and the number of rings on the scutes of the plastron and carapace, he will be able to state accurately the age of any specimen below the age of seven years; and that he will be reasonably certain of the age of the specimens from seven to ten years of age. The overlapping of the groups of the last three years considered may, however, cause difficulty. According to my observations, animals whose carapaces are of over 80.0 mm. in length are at least ten years old.

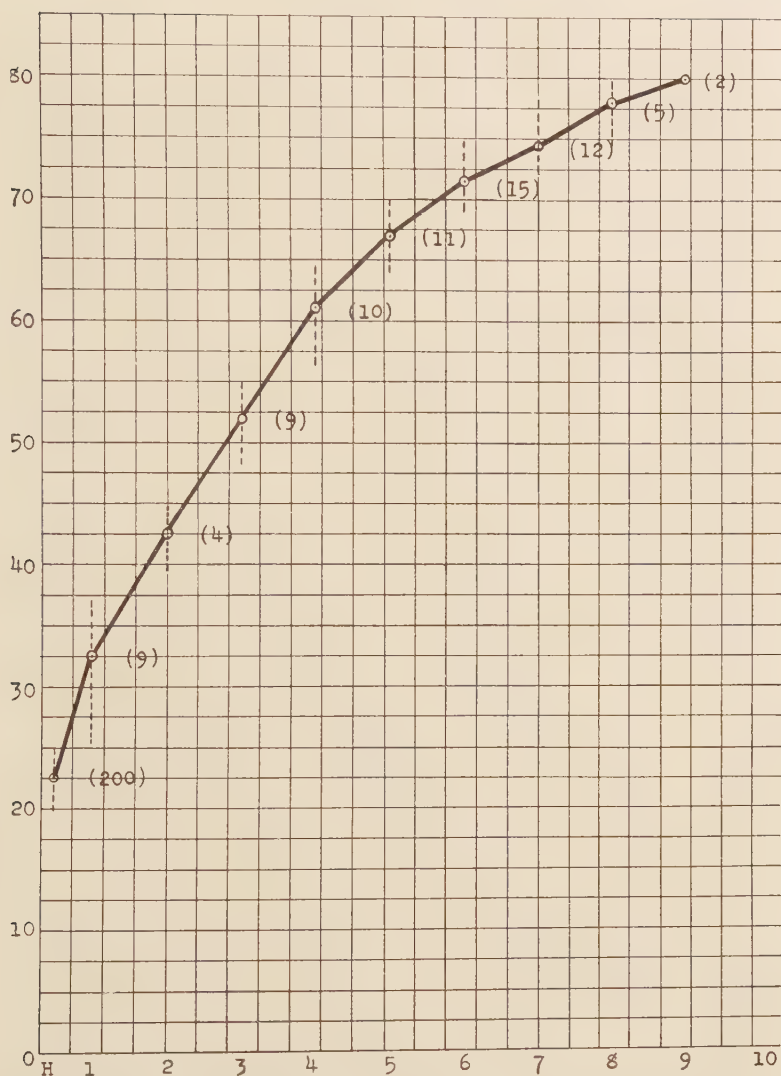


FIG. 79. Curve illustrating growth in *S. odoratus* (Latreille), based upon the carapace length in millimeters (ordinates) and the number of "annual rings" on the scutes (abscissae). The number of specimens in each group is indicated in the adjacent parentheses, e.g. (200). Vertical dotted lines show the variation within each group. The letter H signifies "at time of hatching." Numbers along abscissae correspond to each successive spring following hatching in September

ATTAINMENT OF SEXUAL MATURITY

The data on growth and age of *S. odoratus* were acquired primarily in an effort to determine the number of years which elapse before the turtles become sexually mature. Males and females of the musk turtle do not attain sexual maturity at the same age. An examination of testes and ovaries from the individuals used in the determination of the growth curve given above shows that the males produce motile spermatozoa from four to six years in advance of egg production by the females. If we base our determination of age on the data given in Figure 79, which correspond closely with unpublished data on the general growth of the gonads, the males become sexually mature in their third or fourth year — newly hatched individuals are considered as in their first year — but the females do not attain a size which allows the production of eggs until much later, from the ninth to the eleventh year. Agassiz (1857) states that *C. picta* does not lay eggs until the age of ten or eleven years, and Pearse (1923) agrees that this is the usual time of the first egg-laying by *C. cinerea*. Barney (1922) found that egg production by diamond-back terrapins, when they are fed during the winter, may begin as early as the fourth year, but that it usually begins in the fifth or sixth year. So far as can be determined, there is no other information available concerning the time when sexual maturity is reached by male turtles. It is singular that there should be such a striking difference (four to six years) in the ages of the males and the females when they first become sexually functional.

SEXUAL DIMORPHISM

At the time of hatching it is possible by dissection to be only relatively certain of the sex of a specimen. In order to determine the sex accurately, it is necessary to examine the gonads microscopically. It is impossible to distinguish the sexes by external characteristics until the third or the fourth year, as in the case of the diamond-back terrapin (Barney, 1922; Hildebrand, 1929). As stated above, there is no sexual dimorphism in the size of the bodies of the males and females, and no differences have been noted in the growth rate.

In a previous report (Risley, 1930) I have discussed in detail the anatomical characters which may be used in the identification of the sexes of adults of this species. The two characters which are generally applicable in the diagnosis of the sex of most cheilonian species are also useful in *Sternotherus*. These characters are differences in the tail length and the concavity of the plastron. In the female the plastron is flat, very slightly concave, or slightly convex, and the tail is short, flattened laterally, and usually acutely pointed; in the male, the tail is much longer, circular in transverse section, and is capped by a blunt terminal nail, and the plastron is markedly concave. Besides these differences the skin around the anus of the female is covered with many fleshy, pointed tubercles, which are distinctly more numerous than in the males. On the dorsal side of the tail of the female there is, furthermore, a median longitudinal row of tubercles, which is absent in the males.

One of the most striking male sex characters is a double patch of compact, usually non-pigmented scales on the hind legs. These are situated on the median side of the knee joint, one patch on the distal surface of the thigh, and the other directly below on the proximal surface of the shank (see figures in original paper, 1930). They are present throughout the year and are not in any way correlated with the breeding season. They do not appear, however, until sexual maturity is reached, that is, until mature sperm are formed for the first time (third to fourth year of age).

The plastron is a variable character in the two sexes, not only with respect to its concavity in the males, but also in its size. The plastron of the female is longer in proportion to the length of the carapace than in the male. In the females the length of the plastron is usually above 72 per cent of the length of the carapace; in the males, it is usually below 70 per cent. A few individuals occasionally appear in which the percentage is between 70 and 72 per cent; they cannot be accurately identified by this character. The width of the bridge connecting the plastron with the carapace is also greater in the females than in the males. Another striking difference is the amount of skin which separates the plastral scutes. The exposed area is much wider in the males than in the females,

although there is some variation. Hallowell (1856) described certain sex differences in adults of *S. odoratus*, and also in some younger specimens. I have been unable, however, to confirm all the sex characteristics noted by him, and especially those given for the younger specimens, all of which were over three years of age.

SUMMARY AND CONCLUSIONS

The foregoing observations, made in the region about Ann Arbor, Michigan, have given the following data in regard to the natural history of *Sternotherus odoratus* (Latreille):

1. Emergence from hibernation usually occurs during the last week of March, with young animals appearing about one month later.

2. Data on the sex ratio indicate that the females somewhat outnumber the males.

3. Mating occurs in the spring between the approximate dates of April 1 and May 15; it may also occur in the fall. It appears that the time of mating is largely dependent upon the condition of the testes.

4. Ovulation takes place between the dates of May 15 and 20, and the eggs are normally retained in the oviducts for a period varying from twenty to thirty-five days, during which time the albumen and egg shell are secreted. Under normal conditions eggs are laid between the dates of June 10 and July 5, but this time is also subject to variation.

5. In the laboratory the incubation period of the eggs varies from sixty to seventy-five days after egg-laying. This appears to correspond favorably with the incubation time for eggs in a natural environment. The rate of development may be regulated by changes in the temperature and the humidity of the environment.

6. The number of eggs laid by a single turtle usually varies from three to six, but in exceptional cases as few as one or as many as nine may be produced. The number and the size of the eggs are closely correlated with the sizes of the females producing them.

7. An unusual case of prolonged retention of eggs in the ovi-

ducts, with their eventual retention in the coelomic cavity, is described.

8. Young individuals up to the age of seven years may be placed in year-groups on the basis of the length of the carapaces and the number of annual rings on the scutes of the carapaces and plastrons. Specimens from seven to ten years of age may be identified as such, but there always remains some uncertainty concerning the age determination. Above the age of ten years (carapace length, 80.0 mm.) the age cannot be determined by any known method.

9. Growth during the early years is relatively uniform for all specimens, but all are subject to temporary cessations due to environmental relations and seasonal changes. At first the animals apparently increase rapidly in size, and toward the tenth year there is a gradual slowing of the growth rate.

10. Sexual maturity is attained by males at the age of three or four years. Females mature later; they lay their first eggs between the ages of nine and eleven years.

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